Studies on Characterization and Mechanical Behavior of Banana peel Reinforced Epoxy Composites

A. Lakshumu Naidu[1], D. Raghuveer[2,] P.Suman[3]

Abstract-This paper examines the results of an experimental study based on the engineering properties of banana peel reinforced epoxy composites. Experiments are carried out to study the effect of weight fraction on mechanical behavior of epoxy based polymer composites. The composites were made by varying the weight fraction of banana peel from 0 to 30% and banana peel were made using hand layup method. The fabricated composite samples were cut according to the ASTM standards for different experiments. Hardness test and density test were carried out at the samples. The maximum hardness, density, tensile strength, flexural strength and ILSS are getting for the material prepared with the 20 % reinforced banana peel epoxy composite. Finally the morphology of fractured surfaces is examined by using scanning electron microscopy (SEM) and Energy-Dispersive X-Ray diffraction (EDX). The detailed test results and observations are discussed sequentially in the paper.

Index Terms— Engineering properties, Banana peel, Hardness, density, Tensile strength, Flexural strength, SEM, EDX.

1 Introduction

In this present study to prepare the banana peel particulates of desired particle size different weight percentage in the epoxy matrix. Study the density, micro-hardness, tensile and flexural tests of different samples. Study the nature of failure at the microscopic level by SEM for the tensile and flexural tested samples.

1.1 Composite materials

The advantage of composite materials over conventional materials stem largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. By definition, composite materials consist of two or more constituents with physically separable phases [1, 2]. However, only when the composite phase materials have notably different physical properties it is recognized as being a composite material.

Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties; yet together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material.

1.2 Types of Composites

For the sake of simplicity, however, composites can be grouped into categories based on the nature of the matrix each type possesses [3]. Methods of fabrication also vary according to physical and chemical properties of the matrices and reinforcing fibers.

(a) Metal Matrix Composites (MMCs)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminum, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

- *A Lakshumu Naid[1] is currently working as a Lecturer in Mechanical Department at Centurion University of Technology and Management. Country, PH-08093914965. E-mail: alnaidu@cutm.ac.in*
- *D. Raghuveer[2] is currently working as a Lecturer in Mechanical Department at Centurion University of Technology and Management, E-mail: d draghuveer@cutm.ac.in*
- *P.Suman[3] is currently working as a Lecturer in Mechanical Department at Centurion University of Technology and Management, E-mail: d suman@cutm.ac.in*

(b) Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumina silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density. The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form. There are four classes of ceramics matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and alumina silicates), conventional ceramics (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are fully crystalline), cement and concreted carbon components.

(c) Polymer Matrix Composites (PMCs)

The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the constituents the polymer composites often show excellent specific properties.

1.3 Banana peel

Banana is a citrus fruit mainly originated in New Guinea. It is the most commonly grown tree fruit in the world. Like all citrus fruits, the banana is acidic having pH range 4.5-5.2.
Bananas (Musa ABB) at the color index of 1 (mature green) according to the CSIRO banana ripening guide (CSIRO, 1972) were purchased from the local market. The peels were removed from the flesh with a stainless steel knife. The commercial α-amylase Termamyl 300L Type LS, amyloglucosidase (AMG E) and neutral protease from *B. subtilis* (Neutrase®) were purchased from Novozyme (Krogshoejvej 36, 2880 Bagsverd, Denmark).

1.3.1 Preparation of banana peel powders

Banana peel powder was prepared utilizing four methods: dry milling (DM), wet milling (WM), wet milling and tap water washing (WM-TW), and wet milling and hot water is washing (WM-HW). For the dry milling method, banana peels were dried at 50°C in a hot-air oven overnight, ground by using Udy cyclone mill (Udy cooperation, Colorado USA) and passed a 1 mm screen. The banana peels to water ratio of 1: 5 were blended in a commercial blender and screened through a 1 mm sieve in a wet milling process (WM). After wet milling, the banana peels prepared by WMTW and WM-HW were washed with tap water and hot water at 95°C in the same amount as used in the WM process for 5 min, respectively. The peel samples were dried at 50°C in a hot air oven for 12 hrs and ground to obtain the banana peel powder with a particle size of less than 1.0 mm.

1.3.2 Banana peel powders Particles Size

The collected powders were sieved and a particle size distribution in a sample is given in Table-1. Since the wt% of 212 + microns was around 74.6grams, for the present investigation we have taken this particle size for further experimentation.

TABLE 1 Particles Size

Sample No.	Size range - micron	Size range + micron	Weight grams approx	Weight %
1	--------	1700	21.25	19.12
2	--------	212	75.6	68.16
3	212	150	5.87	4.38
4	150	106	5.17	4.75
5	106	--------	6.18	5.66
		Total	114.07	

1.3.3 Chemical analysis of Banana peel

Moisture content was determined by using a moisture meter at 105°C. Ash, protein, and lipid content were analyzed according to AACC methods 08-01, 46-13 and 30-25, respectively (AACC, 2000). Total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF) contents were determined by enzymatic and gravimetric method of AOAC (Prosky *et al.*, 1988), using a TDF-100 kit obtained from Sigma chemical company, U.S.A.

Color measurements of the banana peel dietary fiber were carried out instrumentally using a color meter (Chroma, CR200, and Japan). The CIE chromaticity coordinates (L*, a* and b*) were measured. The L* values gives a measure of the lightness of the product color from 100 for perfect white

to zero for black. The redness/ greenness and yellowness/ blueness are denoted by the a* and b* values, respectively.

1.4 Epoxy Resin

The type of epoxy resin used in the present investigation is araldite LY556 which is chemically belongs to epoxide family. Its common name is BisPhinol-A-Diglycidyl-Ether.

Epoxy resins (ER) are one of the most important classes of thermosetting polymers which are widely used as matrices for fiber-reinforced composite materials and as structural adhesives [4 – 9]. They are amorphous, highly cross-linked polymers and this structure results in these materials possessing various desirable properties such as high tensile strength and modulus, uncomplicated processing, good thermal and chemical resistance, and dimensional stability [4]. However, it also leads to low toughness and poor crack resistance, which should be upgraded before they can be considered for many end-use applications [4- 5]. One of the most successful methods of improving the toughness of epoxy resin is to incorporate a second phase of dispersed rubbery particles into the cross-linked polymer [10-12].

II EXPERIMENTAL WORKS

Raw materials used in this experimental work are listed below

1. Natural fiber (Banana peel)
2. Epoxy Resin
3. Hardener

2.1 Composite preparation

A Per-pex sheet mould (dimension 130X100X6mm) figure-3.2 was used for casting the composite sheet. A mould release spray was applied at the inner surface of the mould for quick and easy release of the composite sheet. A calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was taken and mixed with banana peel particulate with gentle stirring to minimize air entrapment. After keeping the mould on a glass sheet (coated with wax) the mixture is then poured into it. Care was taken to avoid formation of air bubbles. Pressure was then applied from the top and the mould was allowed to cure at room temperature for 72 hrs. During application of pressure some amount of epoxy and hardener squeezes out. Care has been taken to consider this loss during manufacturing so that a constant thickness of sample could be manufactured. This procedure was adopted for preparation of 5, 10, 20 and 30% weight fractions of orange peel. After 72 hrs the samples were taken out of the mould, cut into different sizes and kept in air tight container for further experimentation.

The experimental procedures followed to determine their mechanical characterization are:

a. Density measurement
b. Hardness test
c. Tensile test
d. Flexural test

2.2 Density Measurement

The density of composite materials in terms of volume fraction is found out from the following equations

$$S_{ct} = \frac{W_0}{(W_0) + (Wa - Wb)}$$

Where ϱ_{ct} represents specific gravity of the composite,

W_0 represents the weight of the sample; W_a represents the weight of the bottle + kerosene,
W_b represents the weight of the bottle + kerosene + sample,
Density of composite = Sct * density of kerosene.

The theoretical density of composite materials in terms of weight fraction is found out from the following equations as given by Agarwal and Broutman.

$$\varrho_{ct} = \frac{1}{\left(\frac{Wf}{\rho f}\right) + \left(\frac{Wm}{\rho m}\right)}$$

Where *W* and ϱ represents the weight and density respectively. The suffix *f, m* and *ct* stand for the fiber, matrix and the composite materials.

The void content of composite sample has been determined as per ASTM D-2734-70 standard procedure respectively. The volume fraction of voids (Vv) in the composites was calculated by using equation:

$$V_v = \frac{(\rho t - \rho a)}{\rho t}$$

Where ϱ_t and ϱ_a are the theoretical and actual density of composite respectively

2.3 Hardness Test

Leitz Micro –hardness tester was used for Hardness measurement. This tester had a diamond indentater, in the form a right pyramid with a square base and an angle 136°

between opposite faces, is forced in to the material under a load ranging from 0.3 to 3 N. Vickers hardness number is calculated by using the following equations.

$$L = \frac{X+Y}{2}$$

$$Hv = \frac{0.1889\ F}{L^2}$$

Where F is the applied load, L is the diagonal of square impression (mm), X is the horizontal length (mm), and Y is the vertical length (mm).

2.4 Tensile Test

The tension test is generally performed on flat specimens. The most commonly used specimen geometries are the dog-bone specimen and straight-sided specimen with end tabs.
The standard test method as per ASTM D3039-76 has been used. The length of the test specimen used is 150 mm. The tensile test is performed in universal testing machine (UTM). The tests were performed with a cross head speed of 0.5mm/min. For each test composite of four samples were tested and average value was taken for analysis. Figure shows the machine used for the test and the sample in loading condition.

2.5 Flexural Strength

The three point bend test was carried out in UTM machine in accordance with ASTM D2344-84 to measure the flexural strength of the composites. The loading arrangement for the specimen and the photograph of the machine used are shown in Figure respectively. The entire specimens were of rectangular cross section of (150x20x5) mm. A span of 100 mm was 16 used for the test specimen. The specimens were tested at a crosshead speed of 0.5mm/min. The flexural stress in a three point bending test is found out by using equation.

$$\sigma = \frac{3\ FL}{2bt^2}$$

Where F is the load, b is the width and t is the thickness of the specimen under test.

The short beam shear tests (SBS) are performed on the composite samples at room temperature to evaluate the value of inter-laminar shear strength (ILSS). It is three point bending test which generally promotes failure by inter-laminar shear. The SBS test is conducted as per ASTM standard using the same UTM span length 100mm and cross head speed 0.5mm/min.

The inter-laminar shear strength (ILSS) is found out by using the bellow equation

$$ILSS = \frac{3\ F}{4bt}$$

Where F is the maximum load, b the width of the specimen and t is the thickness of the specimen.

III RESULTS AND DISCUSSION

From Density measurement test, Hardness test, tensile test, Flexural tests the following results are noted.

3.1 Density Measurement

From the table: 2 it is observed that the void fraction percentage of composite increases as the percentage of reinforcement increases still the void content is very less so it shows that the composite fabrication is done properly. Figure: 1 is drawn between the measured densities of the composites and weight fraction of the composite. It is observed that as the reinforcement percentage increases in the epoxy the density increases gradually up to 20% and suddenly decreases at 30% due to void percentage increases the void content increase due to the weight percentage of fiber increases.

Table 2: Density of different Samples

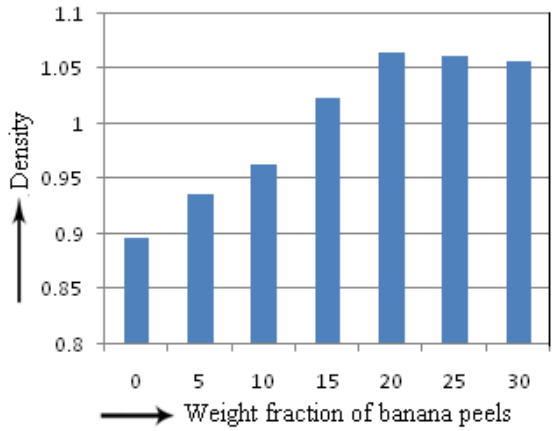

Figure 1: The variation of density with different fiber contents

3.2 Hardness Test

Vickers hardness number is measured by Leitz Micro – hardness tester. The results are tabulated in the table 3. Figure 2 drawn between the harness values of composite and the weight percentage of composite. It is observed that as the reinforcement increases the hardness increases the maximum value is obtained for composite prepared with the 20% composite.

Table 3: Hardness of different samples

S.No.	Weight fraction of particulates (%)	Vickers Hardness value
1	0	17.65
2	5	18.46
3	10	19.78
4	15	20.33
5	20	20.89
6	25	19.93
7	30	18.97

S.No.	Fiber content (%)	Measured Density (gm/cm3)	Theoretical Density (gm/cm3)	Volume fraction of voids (%)
1	0	0.896	0.963	1.236
2	5	0.9356	0.969856	1.4658
3	10	0.9634	0.989635	1.86453
4	15	1.0235	1.056546	2.26554
5	20	1.0645	1.092346	2.79844
6	25	1.0612	1.120372	4.00236
7	30	1.0568	1.156536	5.65423

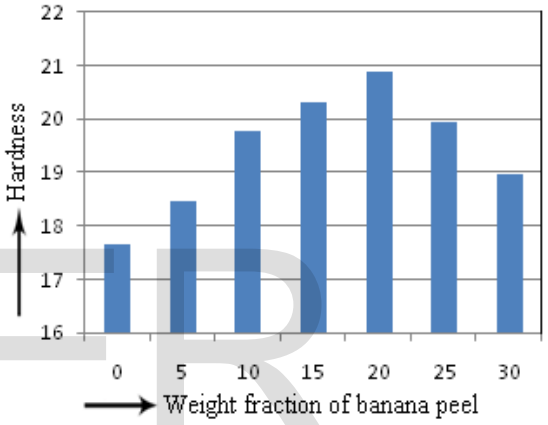

Figure 2: Variation of Vickers Hardness value with different fiber contents

3.3 Tensile Test

The results of tensile test using UTM are tabulated in Table 4. From figure 3 it is observed that the tensile strength is maximum for the composite prepared with 20% fiber However, for 30% fiber composite the tensile strength decreases because of the void content.

Table 4: Tensile Stress and Tensile Modulus of composites

S.No.	Weight percent of fiber (%)	Tensile Stress (MPa)	Tensile Modulus (MPa)
1	0	17.89	648.65
2	5	18.79	746.23
3	10	21.53	1314.56
4	15	23.56	1300.12
5	20	24.78	1285.64
6	25	23.45	1125.71
7	30	21.04	965.76

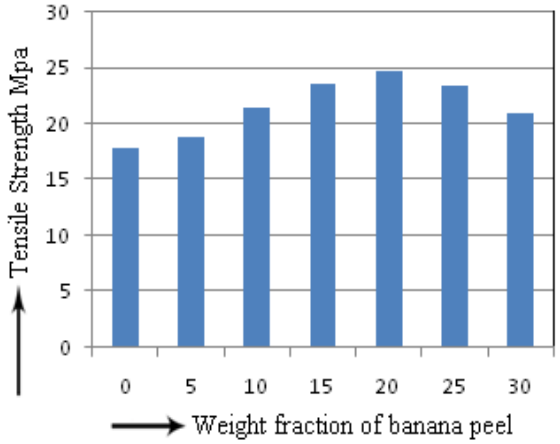

Figure 3: Variation of Tensile strength with different fiber contents

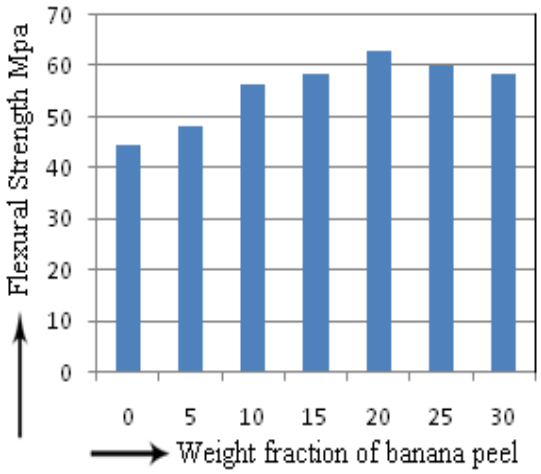

Figure 4: Variation of flexural strength with different fiber contents

3.4 Flexural Test

The three point bend test was carried out in UTM 201 machine in accordance with ASTM D2344-84 to measure the flexural strength of the composites. The flexural strength, flexural modulus and ILSS values are tabulated in Table 5. From the table, it is observed that the composite having 20% fiber content has the highest values of flexural strength, flexural modulus and ILSS. Figure 4 and 5 it is observed that the flexural and ILSS values are getting maximum for the composite prepared with 20 % fiber.

Table 5: Flexural properties of the composites

S.No.	Weight percent of fiber (%)	Flexural Strength (MPa)	Flexural modulus (GPa)	ILSS (MPa)
1	0	44.65	5.032	1.123
2	5	48.32	5.215	1.423
3	10	56.48	9.456	1.642
4	15	58.65	9.865	1.765
5	20	62.86	10.654	1.862
6	25	60.23	9.356	1.703
7	30	58.65	8.456	1.735

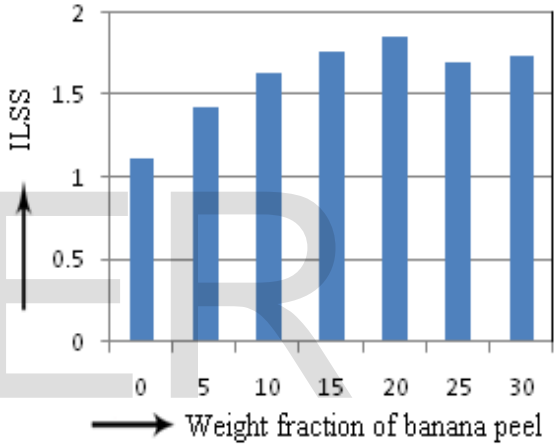

Figure 5: Variation of ILSS with different fiber contents

3.5 SEM Analysis

Scanning electron micrographs (SEM) of resin sample and its respective composites were taken on Leo 435 VP. Figure 6 is the micro graphs of the 20 % banana peel reinforced epoxy composite which is subjected to tensile test. Micrographs clearly show that no debonding, no fiber chipping out and no crack formation it shows that the bonding is strong between the matrix and reinforcement.

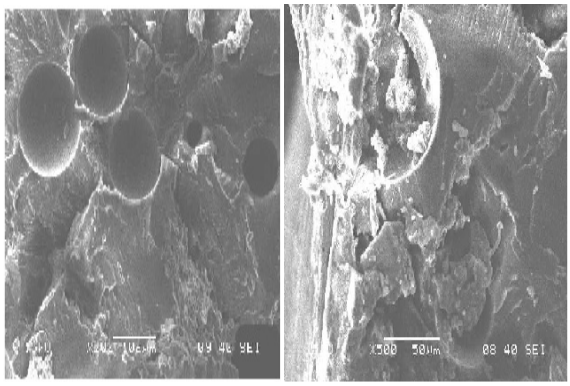

Figure 6: SEM micrograph of 20% banana peel composite after tensile test

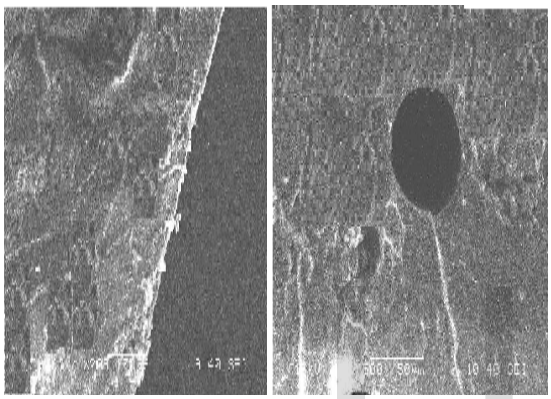

Figure 7: SEM micrograph of 20% banana peel composite after flexural test

Figure 7 is the micro graphs of the 20 % banana peel reinforced epoxy composite which is subjected to flexural strength micrographs clearly show that some bending of fibers are taken place but the fibers are not come out from the epoxy it shows that the bonding is more between the epoxy and banana peel fiber.

3.6 EDX analysis

Energy-dispersive X-ray spectroscopy is an analytical technique used for the elemental analysis or chemical characterization of a sample. It relies on the investigation of an interaction of some source of X-ray excitation and a sample. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing unique set of peaks on its X-ray spectrum.

EDX micrograph of 20% banana peel composite after tensile test and flexural test has been represented in the Figure 8 and 9. It showed the percentage weight of chemical compositions available on the surface of banana peel were as follows: 30.12%, 29.56% of C, 41.81%, 40.65% of O, 15.60%, 14.68% of K, 1.32%, 1.02% of Si, 0.32%, 0.256% of Ca, 2.03%, 1.96% of Na, 0.8%, 0.65% of Al and 2.33%, 2.16% of Mg.

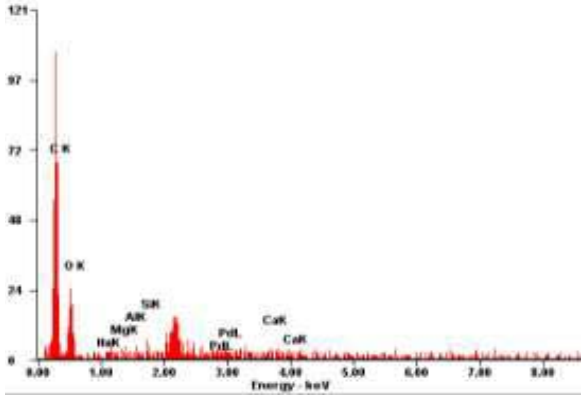

Figure 8: EDX micrograph of 20% banana peel composite after tensile test

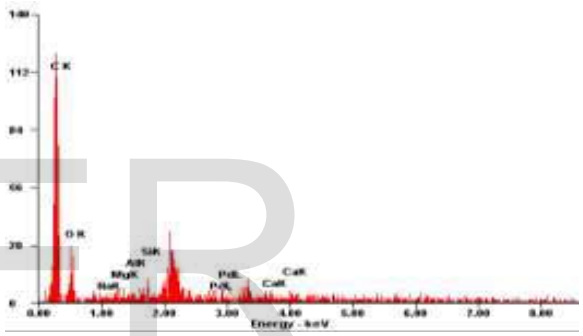

Figure 9: SEM micrograph of 20% banana peel composite after flexural test

IV CONCLUSIONS

The present work deals with the preparation of characterization of waste banana fiber reinforced epoxy composite. A laboratory study has been carried out to determine the mechanical behavior and characteristics of banana peel reinforced epoxy composites by different methods and the following conclusions are drawn.

(1) With the successful fabrication of a new class of epoxy based composites reinforced with banana fiber.
(2) The flexural strength and ILSS of the composite is found to be maximum with 20% weight percent of orange fiber.
(3) The tensile strength of the composite is found to be maximum for the 20 % weight percentage of the orange fiber.
(4) The hardness value of the composite increases with increasing of the fiber content.

(5) SEM observation reveals that most of the fibers were broken instead of pulling out from the matrix. This indicates a good bonding between fiber and the matrix.
(6) The chemical minerals of the banana peel reinforced epoxy composites are determined by EDX Analysis.

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